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CITATION:

MORITA, MASAYUKI ...[et al]. Marauder ant (Pheidologeton affinis) predation of green turtle (Chelonia mydas) nest in Chagar Huntang, Redang Island and measures to protect the nests. Proceedings of the 2nd International symposium on SEASTAR2000 and Asian Bio-logging Science (The 6th SEASTAR2000 Workshop) 2005: 55-62

ISSUE DATE:

2005

URL:

http://hdl.handle.net/2433/44085

Marauder ant (*Pheidologeton affinis*) predation of green turtle (*Chelonia mydas*) nests in Chagar Hutang, Redang Island and measures to protect the nests

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ABSTRACT
In Chagar Hutang, Redang Island, five kinds of ant species have been identified as predators of turtle nests, one of them being the Marauder ant, *Pheidologeton affinis*. In 2004, 4 nests out of 459 were depredated by *P. affinis*. Although *P. affinis* have been found to occur around the vegetation border of the entire beach length, predation incidences occurred mostly at the westernmost part of the beach where the sand is coarse compared to other parts of the beach. The coarse sand appeared to create problems to female green turtles when they excavated the egg chamber resulting in egg chambers in this part of the beach being generally about 9 cm shallower than those found in other parts of the beach. Further, *P. affinis* comprises polymorphic workers of which minor workers were dominant. Minor workers were able to penetrate the shallower turtle nests through gaps in the coarse sand. In 2005, two green turtle nests deposited in the westernmost area of the beach were relocated to other areas with fine and clean sand. Hatchlings emerged from these nests successfully. However, *P. affinis* was able to penetrate one nest in which the sand contained much leaf litter and roots. Replacing the sand around the nest with fine and clean sand appeared successful in saving the nest. In spite of the above-mentioned measures, five nests at other beach sectors with fine sand were depredated, as logs or roots penetrated egg chambers of some nests and *P. affinis* came in through them.

KEYWORDS: *Pheidologeton affinis*, predation, green turtle, Redang Island

INTRODUCTION

Green turtle (*Chelonia mydas*) is an endangered species. SEATRU (Sea Turtle Research Unit) of KUSTEM (Kolej Universiti Sains dan Teknologi Malaysia: College University of Science and Technology Malaysia) has been conducting research and conservation project on turtles since 1993 in Chagar Hutang, located in the northernmost part of Redang Island.

Redang Island is one of the most important nesting sites of green turtle in Peninsular Malaysia. Among the nesting beaches on the island, Chagar Hutang is the major beach with nesting density recorded at approximately 250 to 600 nestings per year (Chan, unpubl.data.). However, nesting density in Chagar Hutang shows a declining but oscillating trend (Chan, unpubl data.). In order to arrest the decline, in-situ egg incubation has been carried out on this beach since 1993 with the aim of protecting 100% of the eggs deposited and optimizing hatchling production. One of the major tasks has been to reduce natural predation of eggs undergoing incubation. On Redang Island, two kinds of ghost crabs, viz. *Ocypode ceratophthalmus* and *Ocypode kuhlii* (Ahmad and Kamarruddin, 2002; John, 1998), water monitor (*Varanus salvator*), maggots, and ants were recorded as predators. In Chagar Hutang, the entire beach is patrolled hourly from 09:00 to 18:00 by volunteers to reduce predation by water monitors and ghost crabs. Water monitors are kept at bay by the presence of patrollers. Ghost crab burrows are filled with sand to avoid secondary predation by flies and terrestrial ants. On the other hand, little is known about ant predation incidences despite a brief report from Peninsular Malaysia (Chan and Liew, 1995; Ahmad *et al*. 2004a; 2004b). In Chagar Hutang, predation incidences by ants have been becoming increasing serious (Chan, unpubl data.). To enhance hatch rates and emergence of hatchlings, it is necessary to investigate ant predation systematically. As a result of the observations on the ant predation in Chagar Hutang in 2004 and 2005, five species of ants (*Pheidologeton affinis, Dorylus* (*Dichthadia*) *laevigatus*, *Paratrechina* sp., *Monomorium* sp. in 2004 and *Hypoponera* sp. in 2005) were identified as predators upon turtle nests. The objectives of this research are to study foraging behavior of *P. affinis* and to establish a measure to protect turtle nests from this ant species.

METHODS

Research Site

Redang Island is located off the east coast of

Peninsular Malaysia (5^{O} 44' – 5^{O} 50' N, 102^{O} 59' – 103^{O} 05' W), Chagar Hutang beach is located the northernmost part of the island. The beach is 350 m long and surrounded by the hills with undisturbed tropical rain forest. Sector number plates (1 to 35) are set on the vegetation border at 10-meter intervals from the east to the west by SEATRU. The beach is divided into three areas by two streams. One flows between Sectors 11 and 12, and another between Sectors 32 and 33. Nesting activities of turtles occur on an open beach and around a vegetation border.

Preliminary study in 2004 (Sampling, Distribution of ant species, and Identification)
A preliminary study on ant predation was conducted from 13 June to 10 October 2004 on alternate weeks in Chagar Hutang. The major sampling method was hand collecting. Whenever different kinds of ants were found, they were collected and preserved in 75% alcohol. Subterranean species were collected from the turtle nests that were depredated by them during nest check and excavation, and preserved in 75% alcohol for later identification in the laboratory of KUSTEM. Nest check and excavation were carried out everyday by staff, research assistants, and volunteers of SEATRU. Two Internet sources (Hashimoto, 2004; Pfeiffer, 2004) were the major identification guides. Body length of collected *P. affinis* was also measured by using a stereoscopic microscope with a camera lucida. As it was difficult to straighten samples, each length of a head (exclusive mandibles in this study), a thorax, a petiole, a postpetiole, and a gaster were measured separately and summed up for body length.

Sand grain particle size
To verify the result of visual and tactual observation of sand grain particle size in 2004, a sand grain particle size analysis was conducted in 2005. Samplings of sand were carried out at each sector from 2 to 5 August 2005. Sampling stations were basically in front of the sector plates at a distance of 1 m towards the sea. In many cases distances from the sector plates were lengthened to where the first turtle nest was located, as some of the sector plates were set in a vegetation zone. At each sector, at least 500 g of sand samples were collected from different depths, viz. 0 cm, 40 cm, and 80 cm. The depth of 80 cm is almost the same depth of bottom of egg chambers. The depth of 40 cm is midway between 80 cm and the ground surface. Samples collected were naturally dried in the laboratory of KUSTEM and later sieved by sieving machine (Octagon Digital manufactured by Endecotts) for 20 minutes with 13 sieves of different mesh size, viz. 4 mm, 2.8 mm, 2.4 mm, 1.4 mm, 1.0 mm, 0.71 mm, 0.50 mm, 0.355 mm, 0.250 mm, 0.180 mm, 0.125 mm, 0.090 mm, and 0.063 mm. Separated sand in each sieve was weighed by an electronic balance. Each value was plotted on semi-logarithmic graph paper to calculate the mean sand grain particle size of each station (Folk, 1974; McBride, 1971).

Relocation of turtle nests
Based on the visual and tactual observation of sand grain in Chagar Hutang beach in 2004, sand grain particle size at Sectors 33 to 35 were coarser than other beach sectors. Therefore, the turtle nests deposited at Sectors 33 to 35 in 2005 were relocated in Sector 30/31. Also, it is necessary to decide the beach sectors with the lowest possibility of predation incidences. At the same time, sand temperature must be considered so as not to change the sex ratio from the original nests. Whether the relocated nests must be located under a shade or on an open beach depends on the original position of the nests. SEATRU has been relocating nests to Sector 30/31, which was found empirically as an ideal area for relocation. Turtle eggs were collected just before female turtles started sand bathing, and immediately transferred to the new hole dug at Sector 30/31. To minimize movement-induced injury to embryos, eggs should be relocated within 1-6 hr after laying eggs (Boulon, 1999).

Observation of nests during beach patrol
Volunteers participating in SEATRU project patroll the entire beach to check all the nests hourly from 09:00 to 18:00. Flexible plastic nets were placed over the turtle nests (1 m square section of approx. 6 cm mesh.) to prevent access by water monitors, As water monitors tried to remove the nets, volunteers drove them away from the nests.

Attention was also paid to the activities of ants around the nests. When *P. affinis* was found above the turtle nests, its activities were disturbed by sweeping it away. If predation upon the nest surrounded by ants has not yet been started, the sand on the ground surface (100 cm in diameter and 10 cm in depth) was removed together with ants and replaced by fine and clean sand from another beach sector. If ants had reached an egg chamber, the sand above the egg chamber was replaced with fine sand, as well. The diameter of the replacement hole was approximately 15 cm.

Nest Check
After 45-days' incubation period, nests were excavated to check condition of the nest contents. Nest checking was carried out at 2 to 3 day intervals until the natural emergence of hatchlings. Basically, the nests were excavated until the top of the egg chamber to confirm the safety of eggs, and then covered back. After the hatchlings hatched, digging was stopped when the first hatchling on the way to the ground surface was found and the hole was covered back. During this activity, ant predation

could be observed.

During nest check activities, if the eggs and/or hatchlings were attacked by *P. affinis*, the nest was excavated. Un-depredated eggs were relocated to another beach sector, and depredated eggs and/or hatchlings were counted. Saved hatchlings were kept in a basin for a while and released on the same night.

Excavation of turtle nests and a depth of egg chambers

After emergence of hatchlings to the ground surface, the nests were excavated to investigate nest contents. When predation incidences were found during nest checking, the nests were also excavated to save living hatchlings and eggs. At each time of excavation, the depth of top and bottom of the egg chamber was measured by SEATRU.

RESULTS

Preliminary study on ant predation in 2004

The following five ant species were identified as predators in 2004 and 2005.

1. *Pheidologeton affinis*
2. *Dorylus (Dichthadia) laevigatus*
3. *Paratrechina* sp.
4. *Monomorium* sp.
5. *Hypoponera* sp. (in 2005)

The number of green turtle nests incubated *in-situ* in Chagar Hutang was 459 in 2004. Fifty nests out of 459 were depredated by ants (Table 1). Table 1 showed that *P. affinis* was a minor predator in Chagar Hutang. Seventeen of the predation incidences occurred when the research on ants was not carried out. Detailed information on each nest depredated by *P. affinis* in 2004 is shown in Table 2. Table 2 shows that the green turtle nests at Sectors 34 to 35 were selectively depredated by *P. affinis* in 2004. Table 3 shows a difference of the depth of egg chambers between two beach sectors. The top of the egg chamber of green turtle at Sectors 33 to 35 was approximately 9 cm shallower than those found in other beach sectors on average. Additional data on hawksbill turtle (*Eretmochelys imbricata*) is also mentioned in the same table as a reference. Two nests of hawksbill turtle were deposited at Sectors 33 to 35, which were shallower than those of green turtle at the same beach sectors. One of them was depredated by *P. affinis* and another by *D. laevigatus*.

Table 1: Breakdown of number and rate of depredated nests by ants in 2004

Ant Species	No. of depredated nests		Predation Rate per depredated nest (%)	Predation Rate per total number of nests (%)
	Egg	Hatchling		
Dorylus laevigatus	28		56.0	6.1
	10 (35.7)	18 (64.3)		
Pheidologeton affinis	4		8.0	0.9
	4 (100)	0 (0)		
Monomorium sp. and *Paratrechina sp.* *****	1		2.0	0.2
	1 (100)	0 (0)		
Unidentified ******	17		34.0	3.7
	11 (64.7)	6 (35.3)		
Total	50		100.0	10.9

* : *Monomorium* sp. and *Paratrechina* sp. were found in the same turtle nest simultaneously.

**: The author was not at the research site or ants had left from the depredated nests

Table 2. The information of depredated green turtle nests by *P. affinis* in 2004

Nest No.	Beach Sector	Date of nesting	Date of digging	Method	Top and Bottom of Egg Chamber (cm)
117	19 / 20	31 May	29 July	Excavation	54.5 / 65.6
179	34 / 35	17 June	8 Aug.	Nest Check	41.5 / 57.0
332	34 / 35	27 July	24 Sept.	Excavation	Not measured
366	34 / 35	7 Aug.	20 Sept.	Nest Check	Not measured

Table 3: Comparison of average depth of turtle nests in 2004. Numbers of the nests measured are shown in parentheses. (Unit: cm)

	Sectors 1 to 33	Sectors 33 to 35	
	Green Turtle	Green Turtle	Hawksbill
Top of Egg Chamber	62.5 ± 11.6 (270)	53.4 ± 11.1 (8)	36.2 ± 12.6 (2)
		50.0 ± 13.3 (10)	
Bottom of Egg Chamber	75.0 ± 10.6 (272)	67.6 ± 9.7 (8)	50.7 ± 7.3 (2)
		64.2 ± 11.5 (10)	

Sand grain particle size and a relocation of turtle nests in 2005

Samplings of sand were carried out at each sector from 2 to 5 August 2005 to verify the result of visual and tactual observation of sand in Chagar Hutang beach in 2004. The mean sand grain particle sizes at each sector are shown in Fig.1. Results of the analysis supported the results of visual and tactual observation of sand in 2004. Sand grain particle size at Sectors 33 to 35 was bigger than those at other beach sectors. This posed difficulties for female turtles to dig deep nests due to coarse sand at Sectors 33 to 35. Shallower nests might allow *P. affinis* to reach egg chambers easily. This result of the analysis supports appropriateness of relocation of turtle nests from beach sectors with coarse sand to other beach sectors with fine sand.

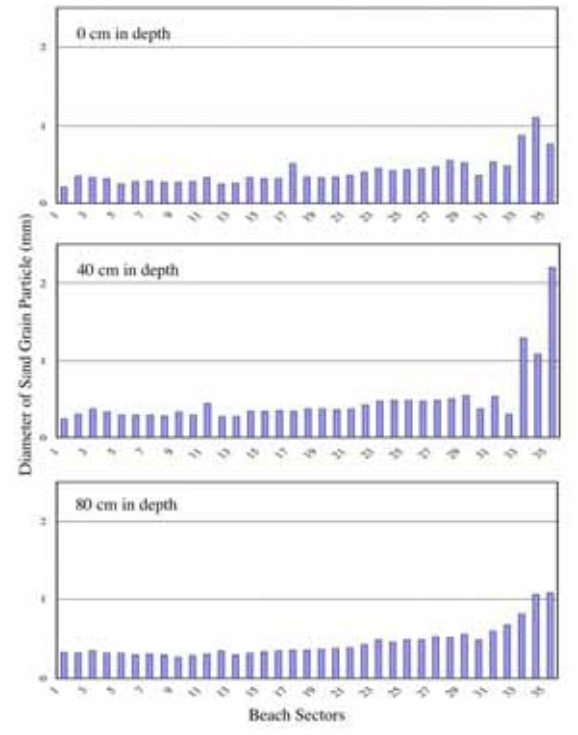

Fig. 1. Mean of sand grain particle size from different depth at each sector (top: 0cm, middle: 40cm, bottom: 80cm)

Green turtle nests depredated by ant species in 2005

Two hundreds and twenty one nests of green turtle were counted in 2005. Forty nine nests of green turtle were depredated by ant species. Two nests of green turtle were relocated from Sector 34/35 to Sector 30/31 where the sand was finer. Hatchlings emerged from both of the nests without attack by *P. affinis*. However, five nests out of 221 nests were depredated by *P. affinis* at the sectors with fine sand. Predation incidences by *P. affinis* and *D. laevigatus* were not observed around Sectors 30 to 32 (Fig. 2). The percentages of predation of the eggs in three nests from Sectors 30 to 32 were 17.6%, 40.4%, and 6.4%, respectively. As depredated eggs were not fully eaten and ants had gone, the incidences seemed to be caused by *Hypoponera* sp., as *P. affinis* and *D. laevigatus* show mass raiding.

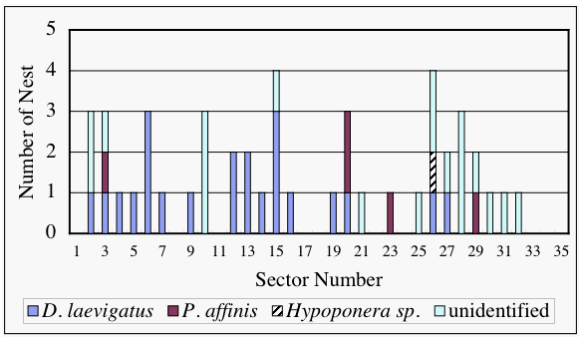

Fig. 2. Distribution of the depredated nests by ant species in Chagar Hutang beach in 2005

Depredated nests by P. affinis *in 2005*

Five depredated nests by *P. affinis* were found during nest checking and excavation at the fine sand beach sectors (Table 4). In spite of conservation efforts, it was difficult or impossible to avoid these predation incidences. In the case of Nest No. 157 and 207, activities of *P. affinis* could not be observed on the surface around the nests. *Pheidologeton affinis* might reach egg chambers through thick roots. In the case of Nest No.105, the ant activity on the ground surface above the net was observed during beach patrol. The ants digging tunnels to the egg chamber encountered hatchlings on the way to the ground surface.

Table 4. Green Turtle Nests depredated upon by *Pheidologeton affinis* in 2005

Nest No.	Sectors	Method	Predation
055	20 / 21	Excavation	Many dead ants in the egg chamber
098	20 / 21	Excavation	No record
105	29 / 30	Nest Check	Hatchlings on the way to the surface were attacked.
157	3 / 4	Nest Check	Wooden block beside the egg chamber. Ants on it.
207	23 / 24	Nest Check	Thick root penetrated the egg chamber. Ants on it.

In Nest No.055, many dead workers of *P. affinis* in depredated eggs suggested an interruption of their predation. Depredated eggs were rotten and ants were also broken to pieces. However their heads were still left intact and measurable. The width of their heads was measured and plotted on a bar graph (Fig.4). A body length of *P. affinis* collected from a seriously depredated nest (No.366) was measured in 2004 (Fig.5). Distribution pattern showed minor workers dominant with a participation of major workers in predation upon the nest, which cannot be seen in early stage of predation incidences by this ant species (Morita, unpubl. data). As distribution pattern of a head width of *P. affinis* from Nest No.055 also showed a similar pattern to the one from Nest No.366, namely minor workers dominant with some major workers, predation of the nest was possibly going to a more serious stage. Berghoff *et al.* (2002) mentioned positive correlation between a body length and a head width of *D. laevigatus*. However, further studies are needed to determine whether there is a positive correlation between a head width and a body length of *P. affinis*.

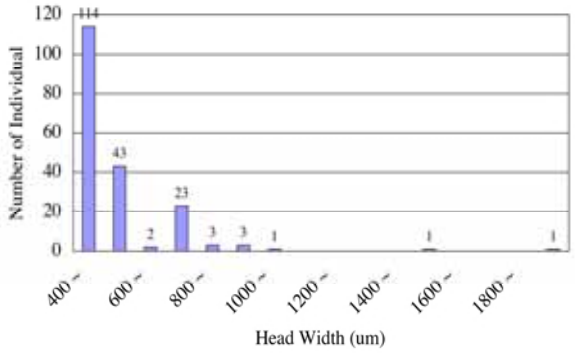

Fig. 4. Head width distribution of Pheidologeton affinis collected from Nest No.055 in 2005

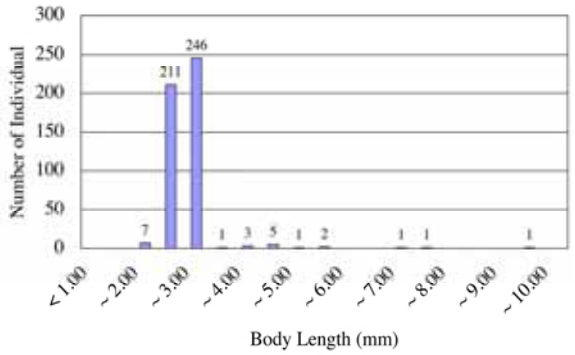

Fig. 5. Body length distribution of Pheidologeton affinis in Nest No.366 in 2004

According to data of the beach patrol, burrows of ghost crabs were found on the ground surface of the nest (Table 5). Those burrows were covered back with sand each time. During the excavation, four eggs were found to be cut and eaten by a ghost crab, and many pieces of *P. affinis* were inside as well. It seemed *P. affinis* reached the egg chamber thorough the crab burrows and started predation, but the ants have died there, as they were isolated by blocking the way back to their nest. It suggested that covering crab burrows during patrol might be an effective measure to stop progress of predation incidences by *P. affinis*.

Table 5. List of predator attacks on Nest No. 055

Date	Time	Predator
4 June	17:13	Water Monitor
4 July	19:15	Ghost Crab
5 July	16:15	Ghost Crab
19 July	18:00	Water Monitor
22 July	12:10	Ghost Crab

Observation of nests during beach patrol in 2005

During beach patrol, activities of *P. affinis* were found on the following three nests (Table 6), and the sand around the nests was replaced with fine and clean sand.

1) Nest No. 079

Eggs were laid in the vegetation zone. Decomposed leaf litter was included in the sand there. A plastic net was fixed over the nest with coral rubbles and a log (approx. 100 cm long and a diameter of 10 cm), which were placed on each corner of the net. *Pheidologeton affinis* dug tunnels under the log and reached the ground surface above the nest. From

there, many minor workers dug small tunnels down toward the nest and reached the egg chamber. The network of the tunnels was dense and caused a small pit (approx. 2 cm in depth and a diameter of 8 cm) with many openings of tunnels. To protect the nest, the sand of the ground surface (approx. 10 cm in depth and a diameter of 100 cm) and to the egg chamber (approx. a diameter of 10 cm) were replaced to the fine and clean sand from Sector 12 (Fig.3). On 3 and 9 July, the egg chamber was checked and no *P. affinis* was found. After that, no ant activity was observed until hatchlings emerged.

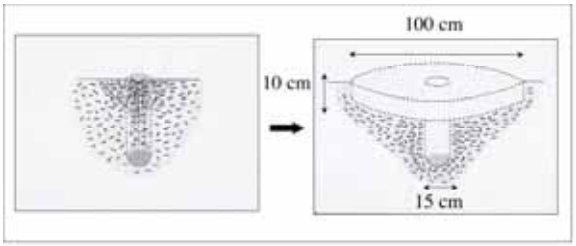

Fig. 3. Nest No.079 was attacked by P. affinis from the ground surface (left). The sand of the ground surface and to the egg chamber was replaced with fine and clean sand (right).

2) Nest No. 099
Pieces of coral rubbles were put on the net as weights. Satellites of *P. affinis* was first observed at 15:10 on 23 July under the coral rubbles, which were immediately removed together with sand around the surface. Fine and clean sand was scattered there. At 18:03 on the same day, *P. affinis* came to the surface again and was swept away. No *P. affinis* activity was found after that.

3) Nest No. 194
At 13:45 on 9 October, many openings of *P. affinis* were found on the ground surface above the nest. The area was in a circle of 1 m diameter. *Pheidologeton affinis* was active on the surface. However, when the surface was excaavated 30 cm in depth towards the egg chamber, no *P. affinis* were found. They had not reached the egg chamber. Later on, the sand on the surface, 10 cm in depth and 1 m in diameter of the area, was replaced with fine sand from another beach sector. The original sand included lots of leaf litter. After the treatment, the nest was checked every hour from 09:00 to 18;00 everyday. No *P. affinis* was recorded for four days. At 09:00 on 15 October, a small colony of *P. affinis* was found under coral rubble just beside the nest, which was disturbed by hands immediately. The coral rubble was removed. However, at 16:00 on the same day, *P. affinis* was found at the same place, which was swept away by hands again. After that, no *P. affinis* was found there until 29 October when the project of this year ended.

Other ant activities were found under coral rubbles of three turtle nests at the beach sectors with fine sand, viz. Nest No. 061 at Sector 2/3, Nest No. 080 at Sector 3/4, and Nest No. 123 at Sector 29/30. *Pheidologeton affinis* started digging tunnels. The coral rubbles were removed and ants were simply swept away. No ant activity was observed later on.

Table 6. Green turtle nests that were attacked by *Pheidologeton affinis*. Sand around the nests was replaced.

Nest No.	Date of nesting	Sector No.	Date of finding *P. affinis*	Date of emergence	Depth of Egg Chamber (cm)
079	21 June	25/26	25 June	16 Aug.	38 - 70
099	1 July	4 / 5	23 July	4 Sept.	62 - 72
194	31 Aug.	13/14	9 Oct.	Did not emerge as of 29 Oct.	

DISCUSSION
Eight green turtle nests could be protected from the predation of *P. affinis* by relocation (two nests), replacing sand (three nests), and sweeping away the ants (three nests) in 2005. As little is known about ant predation upon turtle nests, the information about the measures to protect turtle nests in a simple and costless way will be useful to turtle conservationists

In 2004, predation incidences by *P. affinis* occurred mostly at the beach sectors of coarser sand. As *P. affinis* is a terrestrial ant species, it seems to have difficulty to dig tunnels to egg chambers at the beach sectors with fine sand. Minor workers might pass through gaps of coarse sand grains to reach egg chambers. Some of the nests in the early stage of predation by *P. affinis* contained only minor workers (Morita, unpubl. data). However, predation incidences by *P. affinis* occurred at the beach sectors with fine sand in 2005. Five nests were depredated and foraging activities (tunnel digging) were observed on six nests. This suggested the possibility of predation incidences by *P. affinis* even at the beach sectors with fine sand whenever it detected turtle nests as food resources. As it may take a longer time for *P. affinis* to reach egg chambers at the beach sectors with finer sand compared to its foraging

activities at the beach sectors with coarser sand, the ant activities might be able to be found before reaching egg chambers by keen observation on the nests during beach patrol.

It is not known why only one predation incidence by *P. affinis* occurred in 2004. In 2004, 459 green turtle nests were counted on the beach, while 221 nests in 2005. Frequent landings and nesting activities of female turtles around the vegetation border might disturb foraging activities of *P. affinis*.

To maximize effectiveness of the above-mentioned conservation measures, the following were proposed.

(a) Clean-up the ground surface and keen observation of leaf litter gathered on the ground surface of nests along the vegetation border and in the vegetation. *Pheidologeton affinis* is a polymorphic ant but majority of the workers ranged approx. 2 to 3 mm in body length. The tiny size made it difficult to observe the ants on the ground surface with leaf litter. There might be the possibility that the activities of the ants would be missed. Also, leaf litter keeps moisture on the ground surface, which attracts ant species. Therefore, cleaning up leaf litter from the ground surface of these nests during beach patrol and beach clean-up activity is recommended. In the case of Nest No. 157 and 207, *P. affinis* approached egg chambers away from the nests and reached the egg chamber. According to the activation of ant predation, *P. affinis* will often appear on the ground surface of the nest. If patrollers could find such ant activities as soon as possible, beach patrol and nest checks might minimize predation incidences. Covering crab burrows is also effective way to block secondary predators into the nests.

(b) Use of a net fixing tool

Turtle nests in Chagar Hutang beach were covered by plastic nets to avoid water monitors' predation. However, it is meaningless if the nets are just placed on the ground surface of the nests. Water monitors can easily remove the net and dig a big hole to reach an egg chamber. Then they eat all the eggs and hatchlings in the nest. Therefore, the nets must be fixed so as not to be removed by water monitors. Usually, coral rubbles (approx. 20 to 30 cm in diameter and 1 to 3 cm thick) and logs, which were obtained easily on the beach, were used as weights of the nets. After placing those objects, safety of the nests from water monitors' predation increased. On the other hand, the objects kept moisture under them provided nesting sites to ants. In addition to *P. affinis*, other common terrestrial ants, viz. *Anoplolepis gracilipes*, *Paratrechina* sp., *Monomorium* sp. built their nests there. To avoid the provision of habitat to ants, alternative tools must be prepared, such as a clasp made by stainless steel (Fig.6). However, more investigation is needed to determine an ideal shape of the clasp.

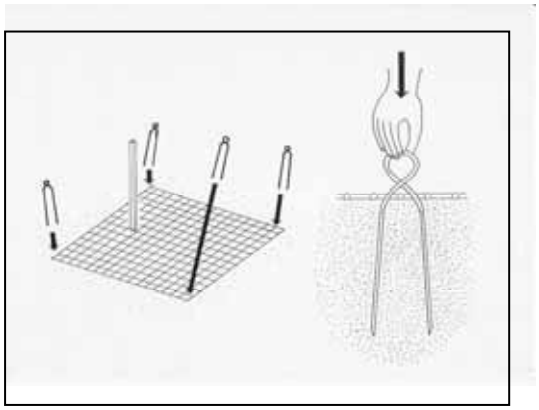

Fig. 6. An image of clasp to fix a net. The wood stick is for marking a position of turtle nest.

ACKNOWLEDGEMENTS

Support and help were obtained from Research Assistants, local staffs, and many volunteers of SEATRU. Free ferry transportation to Redang Island was provided by Laguna Redang Island Resort Sdn. Bhd. and Bejaya Redang Beach Resort Sdn. Bhd. Special thanks to Dr. Stefanie M. Berghoff of University of Bristol for the identification of ants.

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